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Possibilities for Ground Validation of GPM Snowfall Measurements in Northern Europe

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Earth Observation/

Weather Radars

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Why should we perform GV in Northern Europe:

- Observational facilities and data
- Experience in snowfall measurements
- Climate

Most of Finland belongs to boreal forest climate:

- 100-220 snow cover days/year
- Average snow depth in March 20-90 cm

1 km SE from Helsinki

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Preliminary Research Consortium

Finnish Meteorological Institute (FMI, prof. J.Koskinen)

- Precipitation QPE and QPF, quality issues, prec. phase
- Polarimetric scattering modeling (DDA-model), scatterer diagnostics

Technical University of Helsinki (HUT, prof. M.Hallikainen)

- Plans for a reference Ka-band vertically pointing radar

University of Helsinki (UH, prof. M. Kulmala)

- Hydrometeor and aerosol microphysics and radar polarimetry

Finnish Environment Institute (Dr. Vehviläinen)

- Hydrological end user

NASA, Environment Canada (funding possible from Finnish Agency for Technology and Innovation in 2007)

European union FP7 (RAINCLOUDS)

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Helsinki Testbed 2005 – 2015?

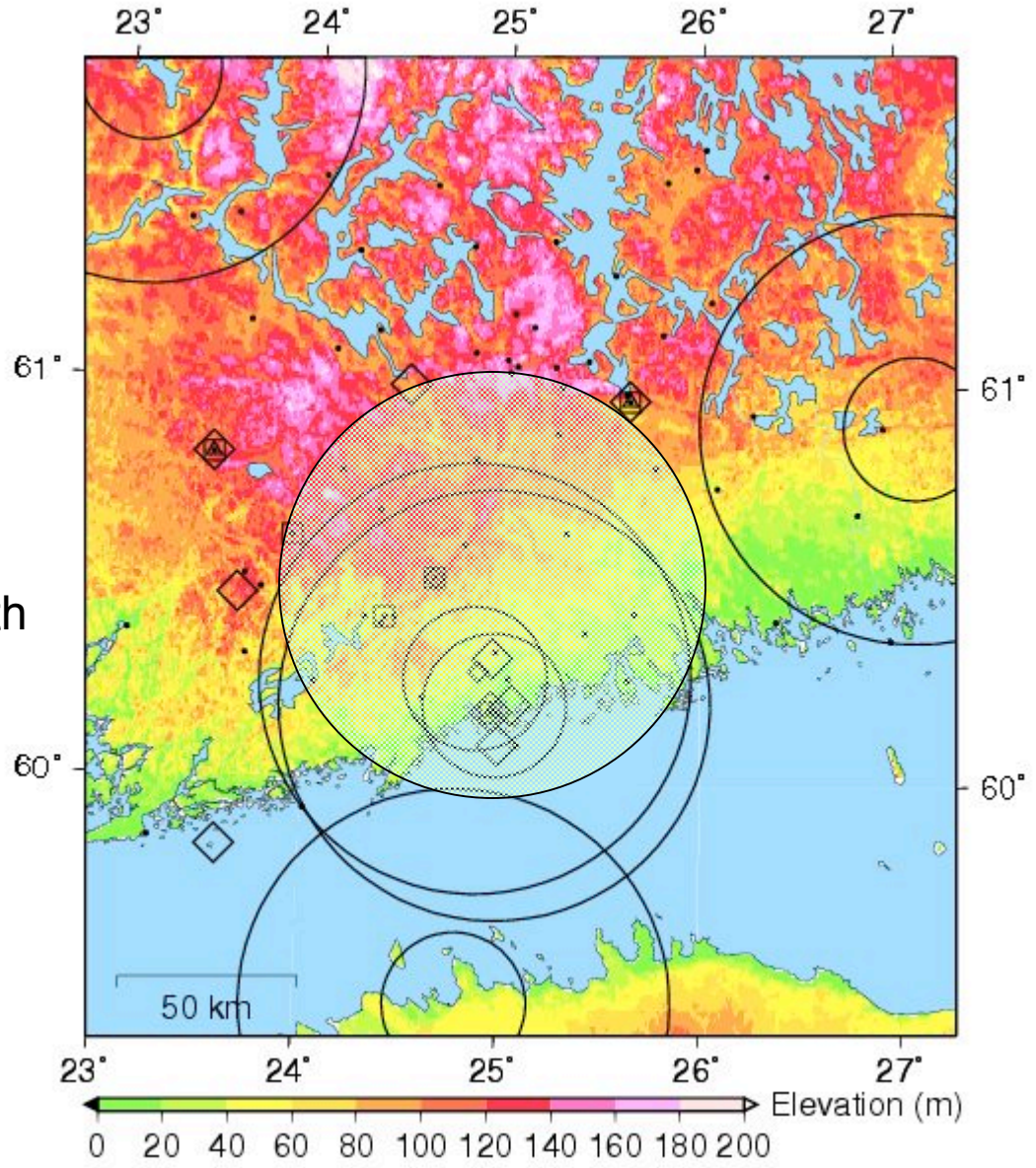
A high latitude research and development facility

Precipitation measurements

- Circles: 4 operational Doppler radars, 1 polarimetric Doppler radar for research
- 2 vertically pointing POSS-radars
- Dots: 80 gauges
- Big diamonds: FD12P optical scatterometers
- Triangles: ultrasonic snow depth
- Squares: weighing gauges

http://testbed.fmi.fi

Public real time data during the campaigns.



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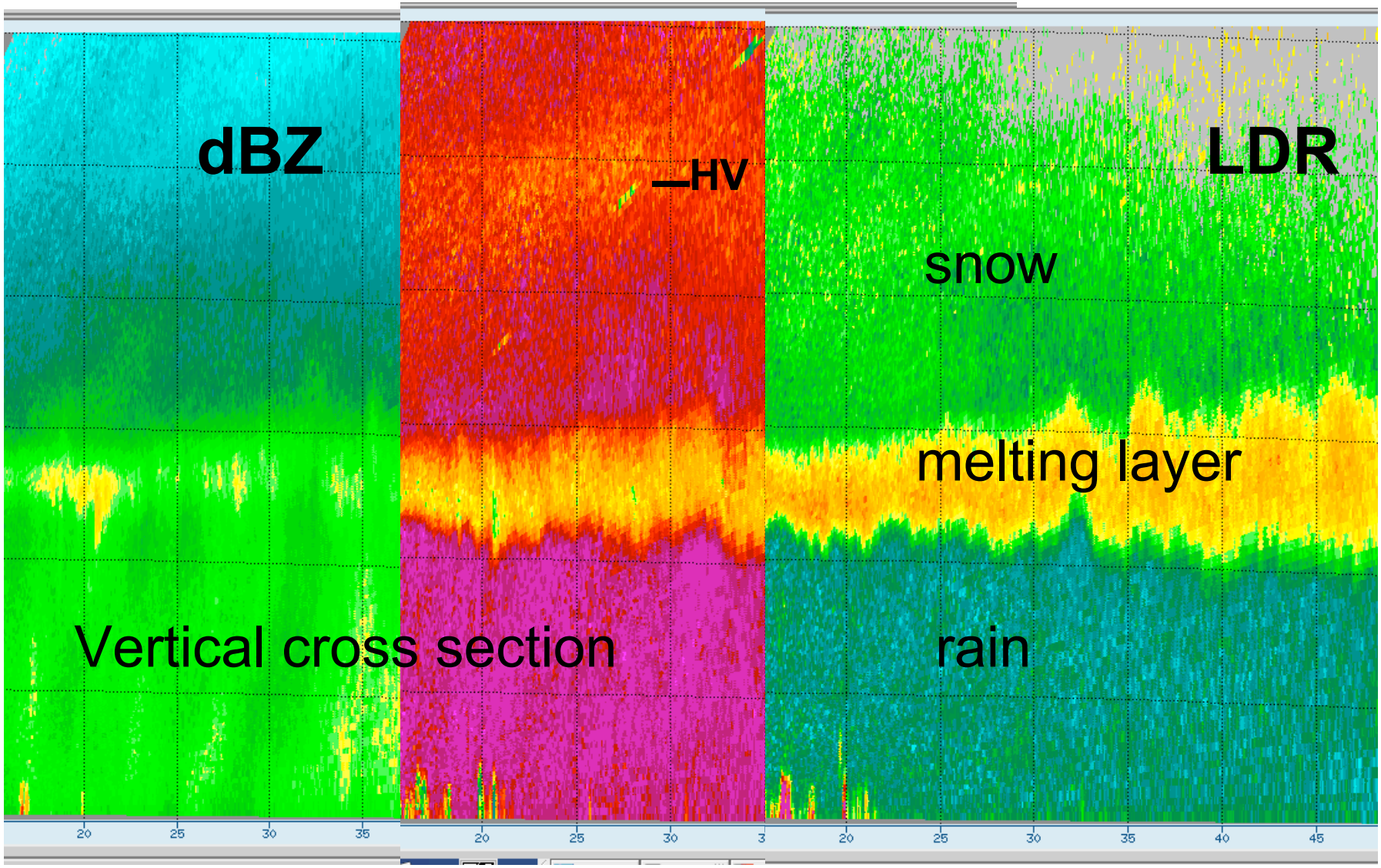
Polarimetric C-band Doppler radar (Vaisala prototype)



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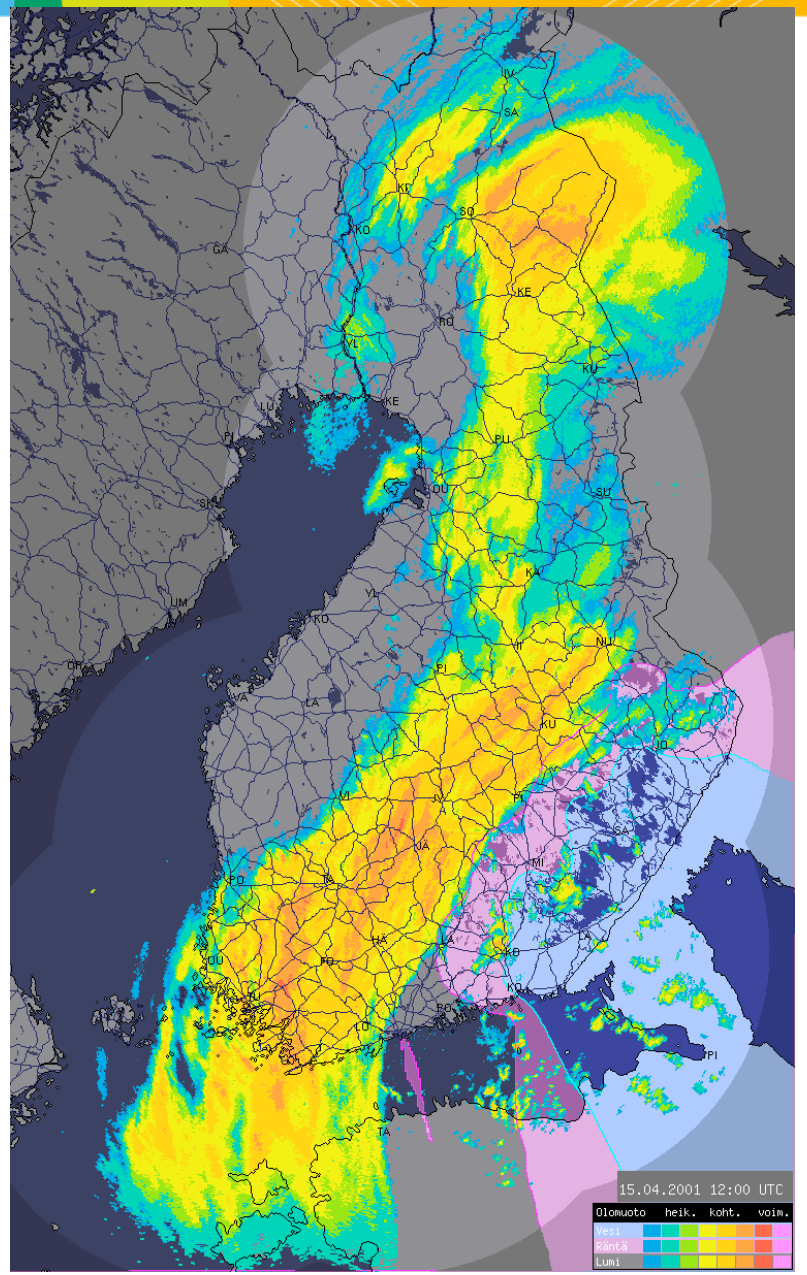
Precipitation type at ground

- Hydrometeor phase analysis (rain, sleet, snow) based on Kriging-analysis of SYNOP data (T,RH). Resolution 5 min & 1 km (extrapolation).
- Time-space variable R(Z) & $S(Z_e)$ -relations.
- Operational since 1999:

  Grey background: snow
  Blue background: rain
  Pink background: mixed



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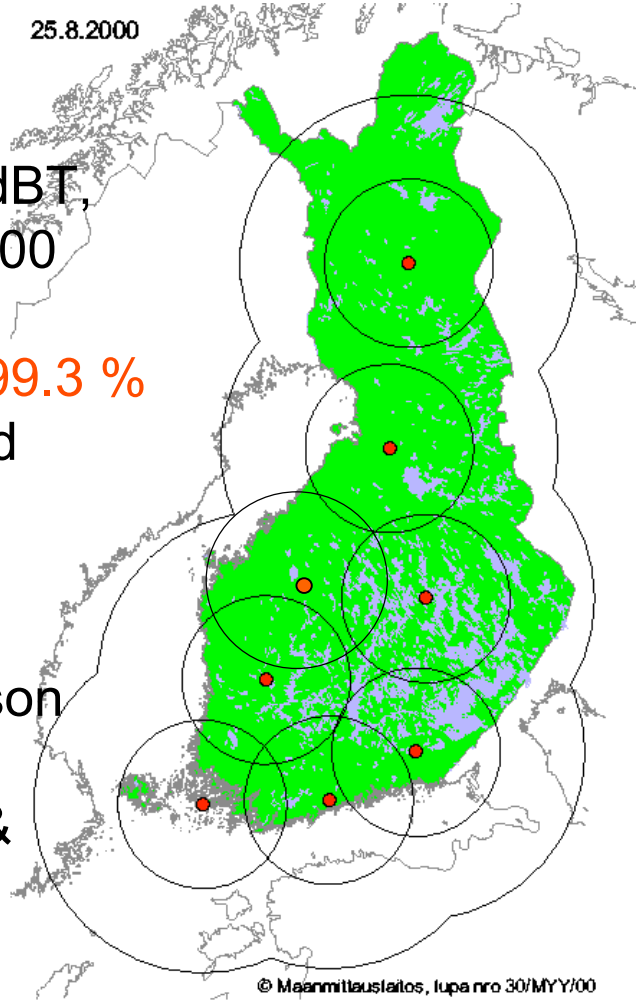
FMI weather radar network


SELEX Sistema Integrati (Gematronik) HW
Vaisala/Sigmet SW (RVP 6-8, IRIS)

- 8 C-band Dopplers
- Volumetric V, dBZ (dBT, W) archived since 2000
- 3D data availability 99.3 % incl. maintenance and telecommunications in 2005
- 15 persons / 10 person years in Technical Services, Research & Weather Service



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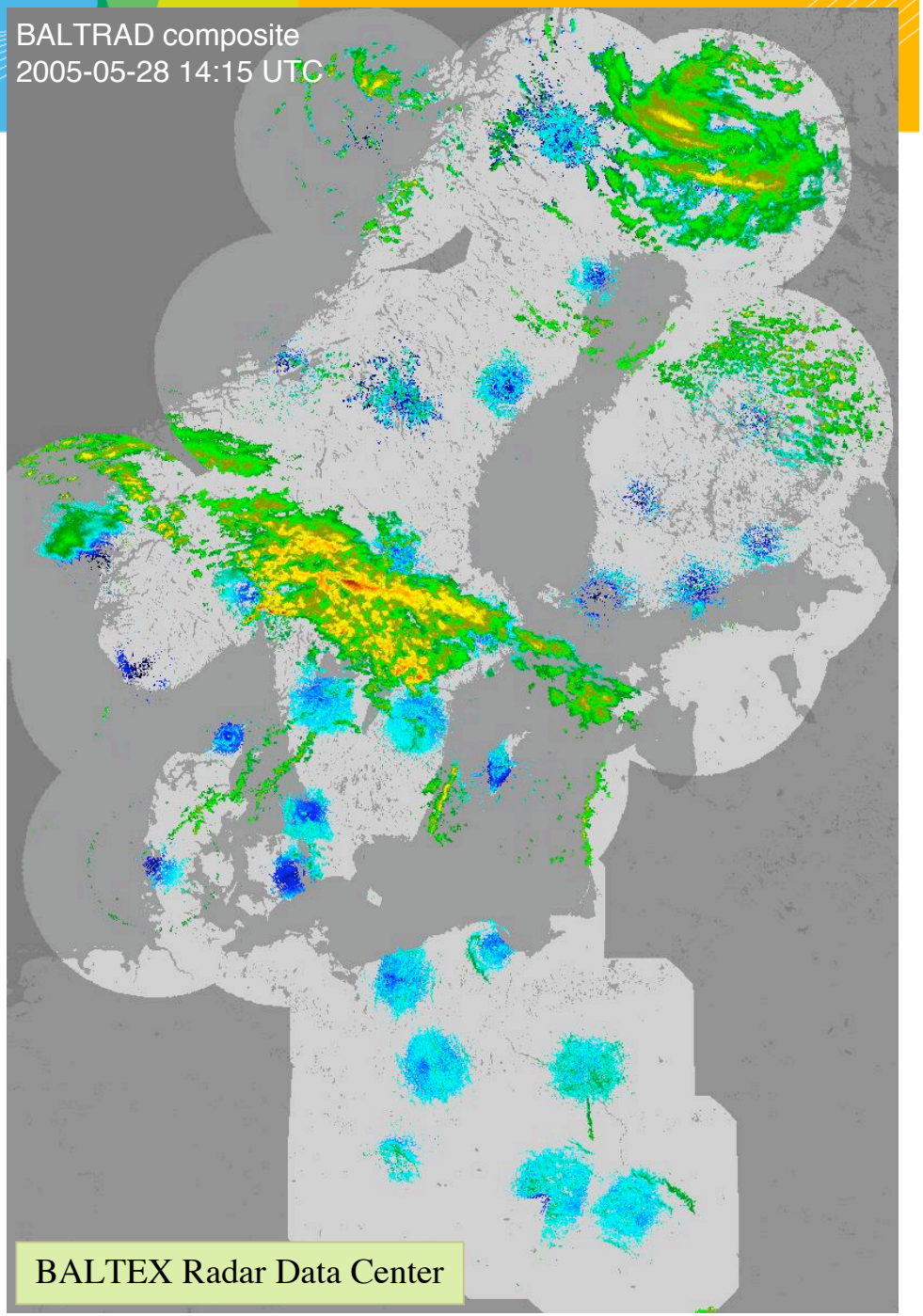
BALTRAD: Composites of radar reflectivity up to 2012 (at least)

- **More than 30 radars in 11 countries:** BALTRAD
- **Radar Data Centre at SMHI, Sweden (Daniel Michelson)**
- **Continuous operation since October 1, 1999**
- **Resolutions: 2×2 km, 15 minutes, 0.4 dBZ**

http://www.smhi.se/brdc



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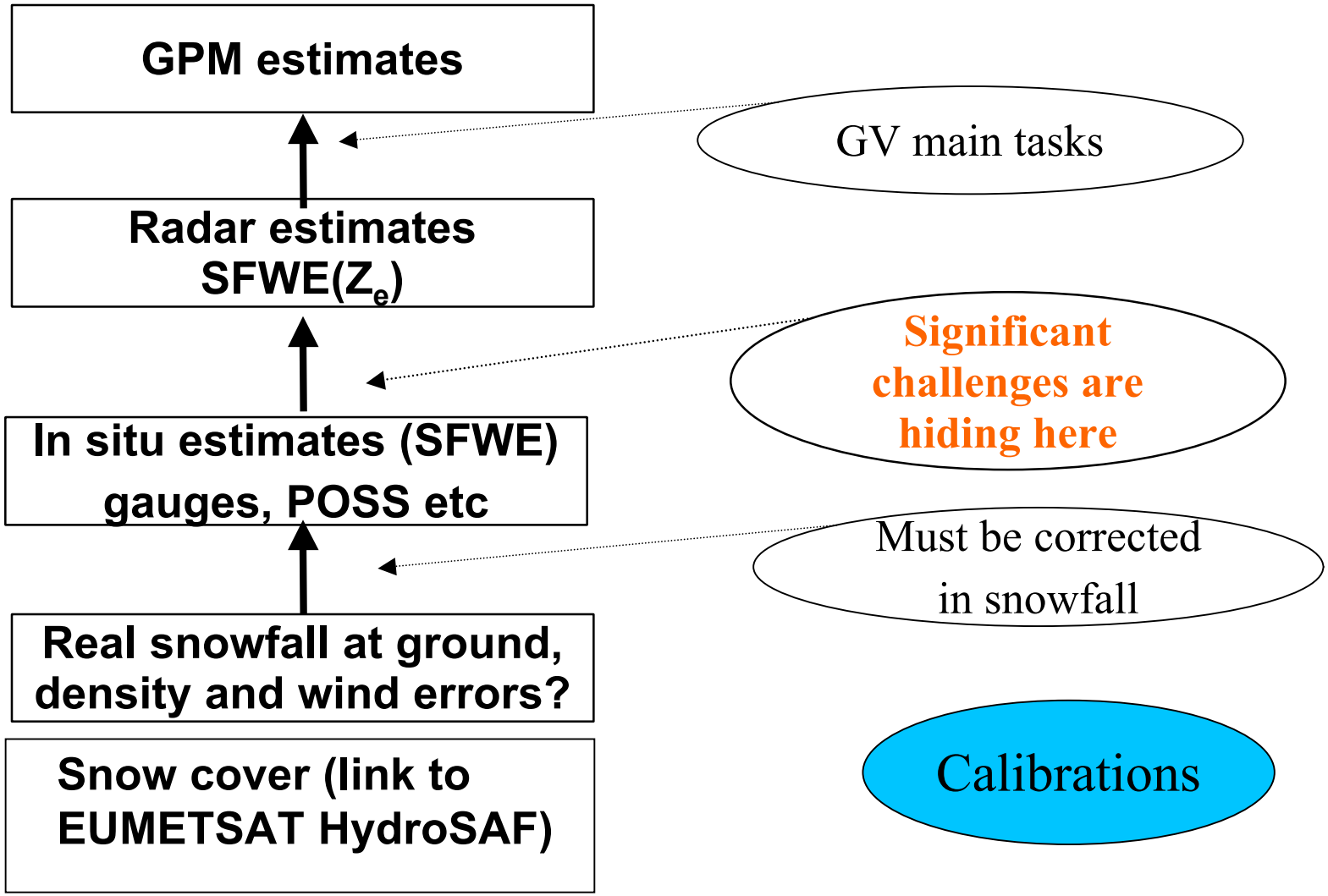
Ground reference process of GPM snowfall measurements

SFWE = SnowFall Water Equivalent



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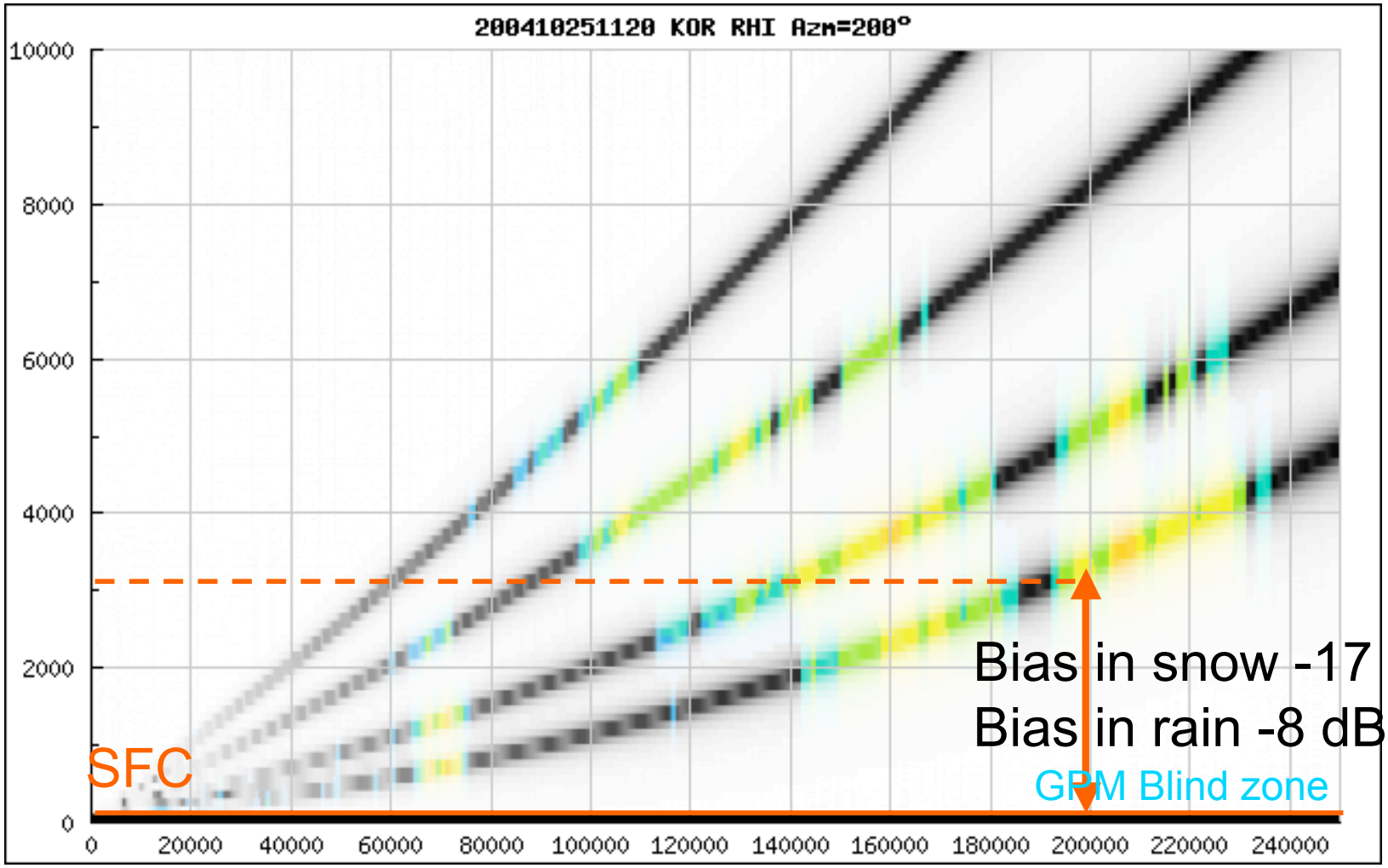
Major challenge: Sampling differences between GPM, radars and surface



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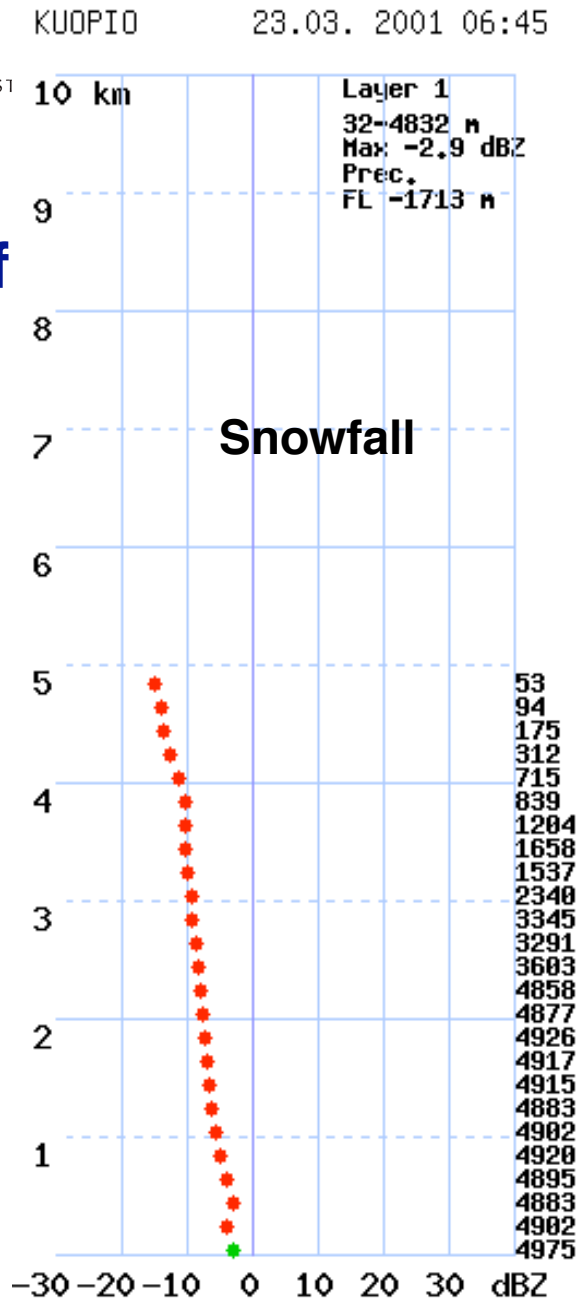
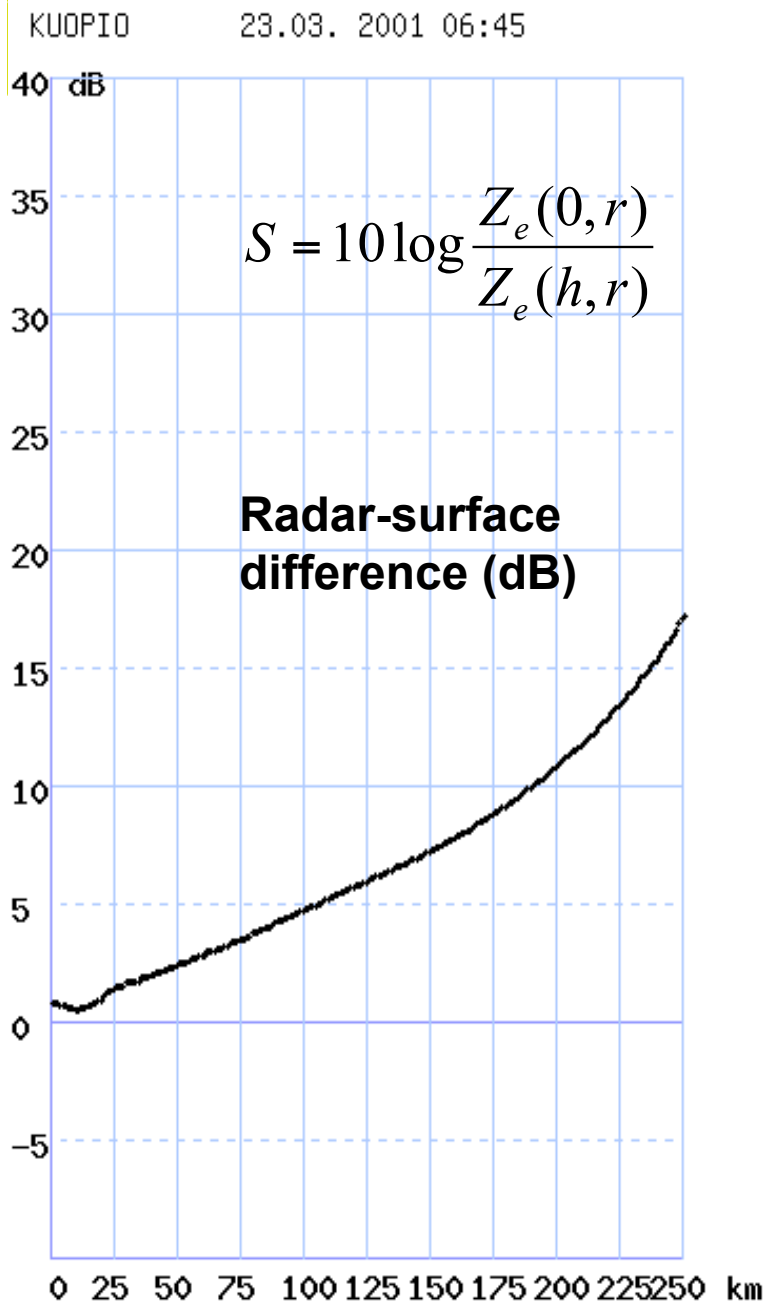
Main factor: Vertical Profile of Reflectivity (VPR)

The FMI operational VPR treatment contains:

- Automatic VPR-type classification
- Correction to obtain surface precipitation
- Archive of ~1 million VPRs





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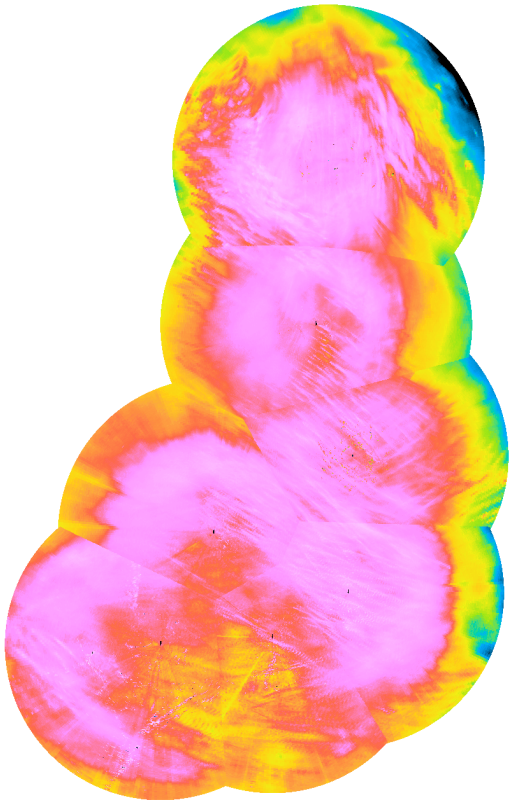
24 h accumulated precipitation June 14, 2004, 17 UTC

500 m PsCAPPI radars “as usual”



Estimated surface precipitation

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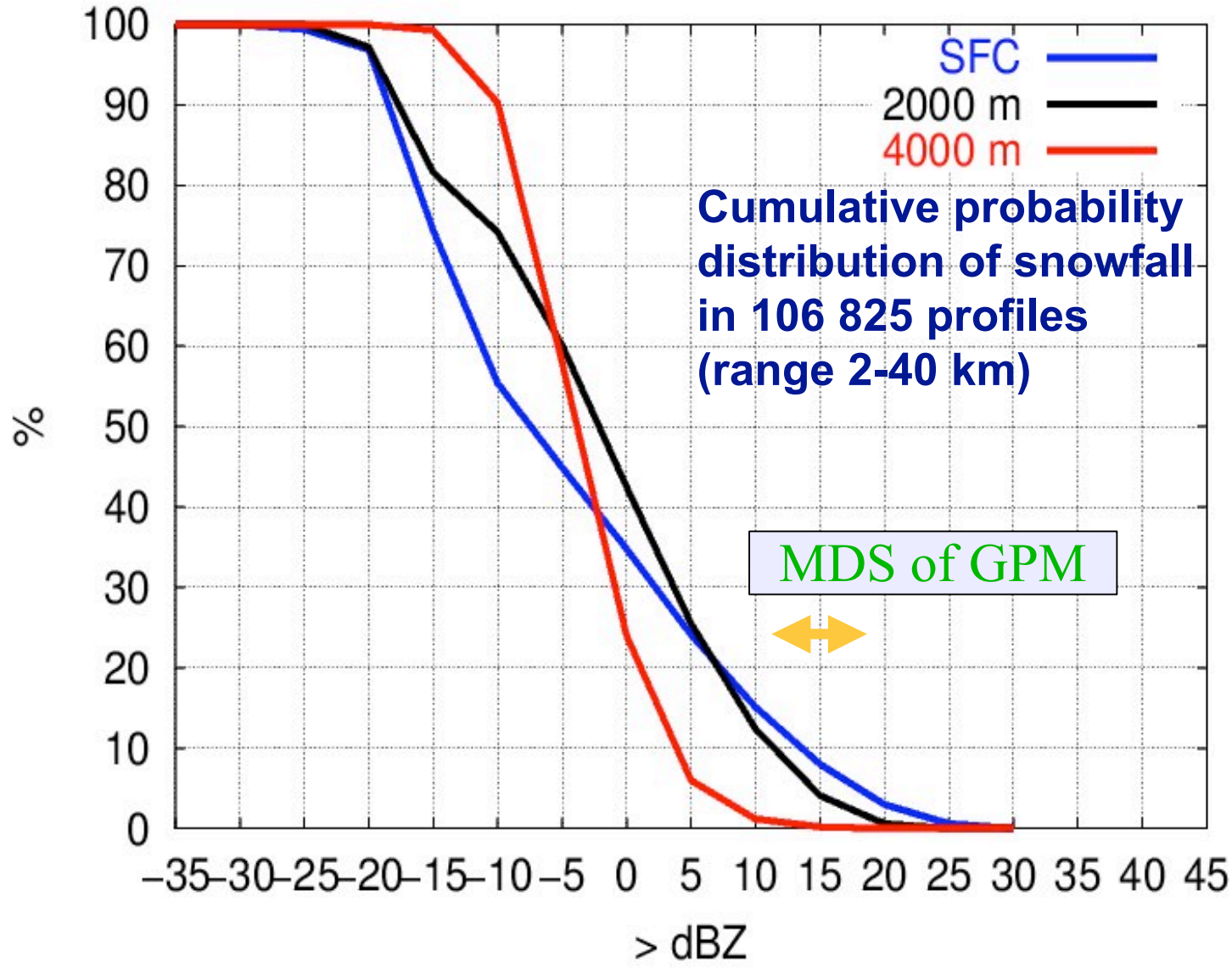
GPM snowfall measurements require 20 dBs more sensitivity than those of rainfall



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Conclusions

A high quality ground validation of GPM snowfall measurements will require:

- Maximal sensitivity of the satellite DPRs
- Good sensitivity, density and high availability of the 3D volume data of a ground based radar network
- Proper climate (frequent snowfall on a flat terrain)
- A collection of several *in situ* snowfall reference instruments at ground level.
- Stable correction algorithms of standard *in situ* snowfall measurements (e.g. wind deflection)
- Good knowledge of the sampling differences between ground level – radar – satellite and their adjustment algorithms, especially the effects of VPR

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Back up slides

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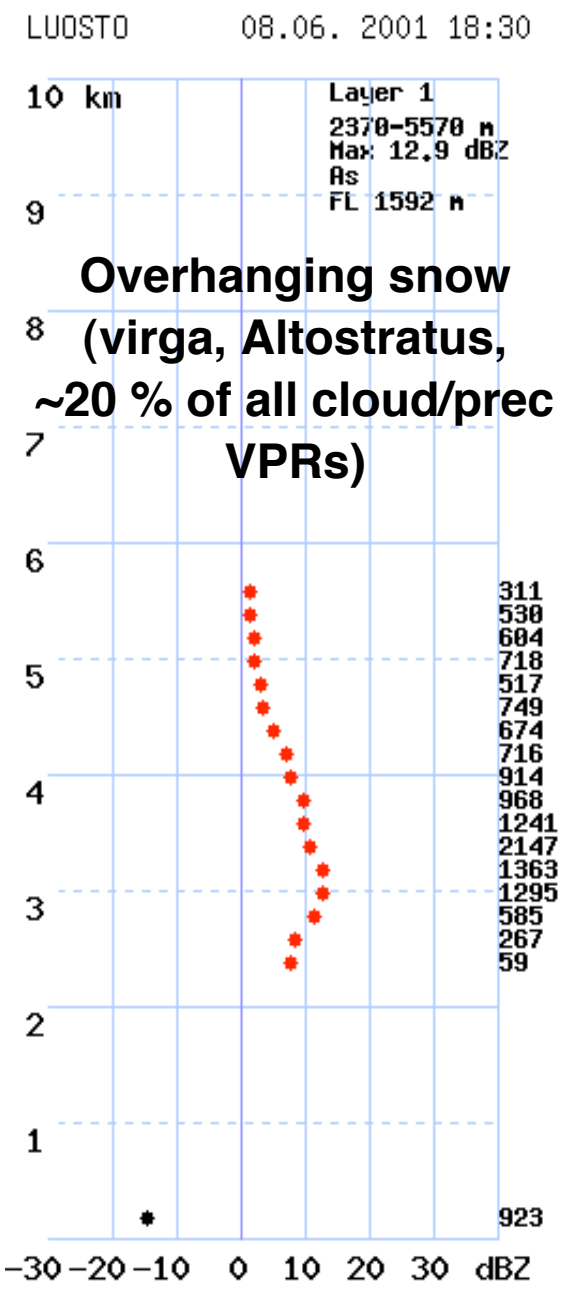
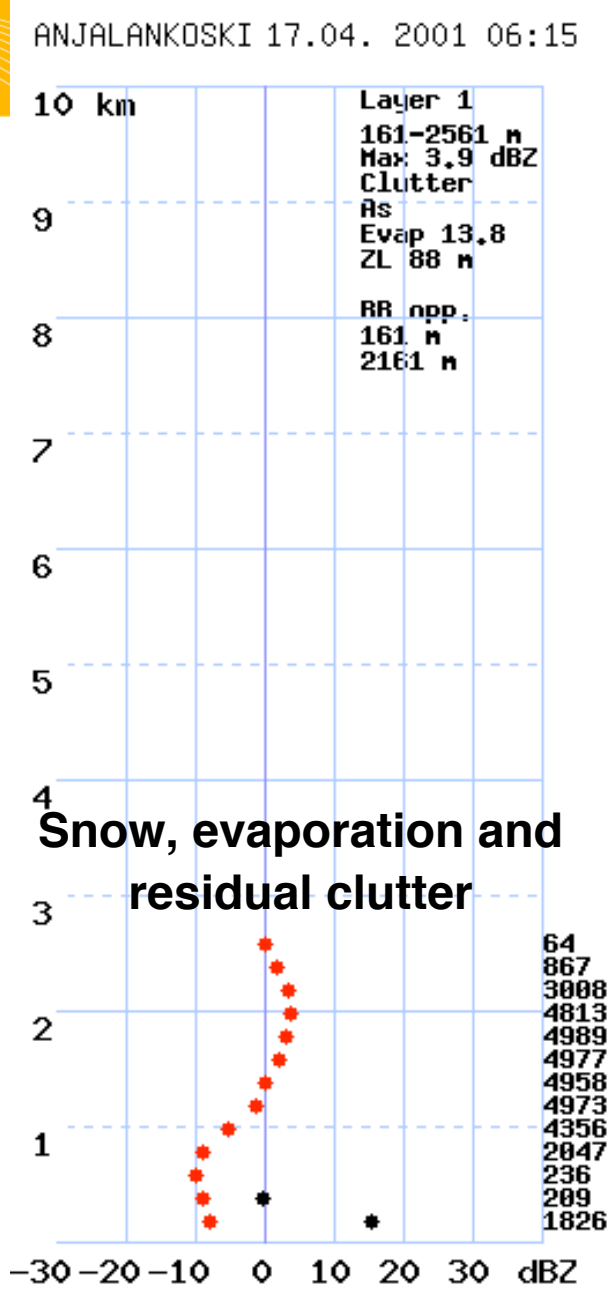
Examples of measured snowfall VPRs



Overhanging snow (virga, Altostratus, ~20 % of all cloud/prec VPRs)



Snow, evaporation and residual clutter

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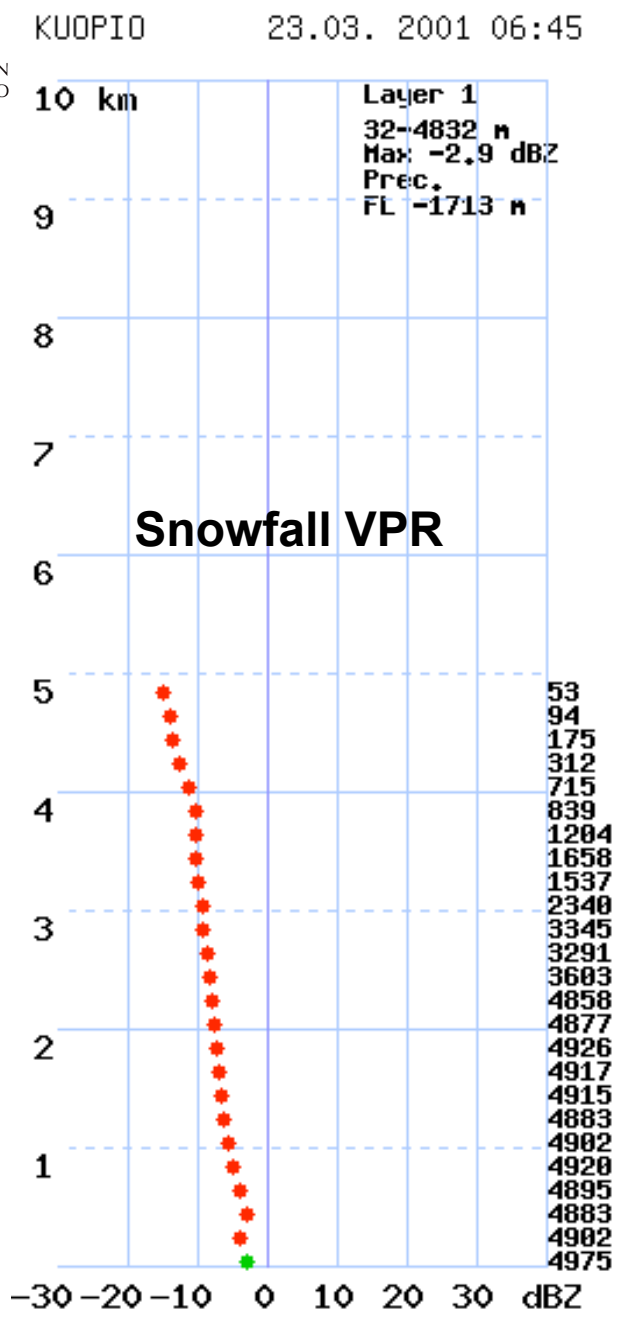
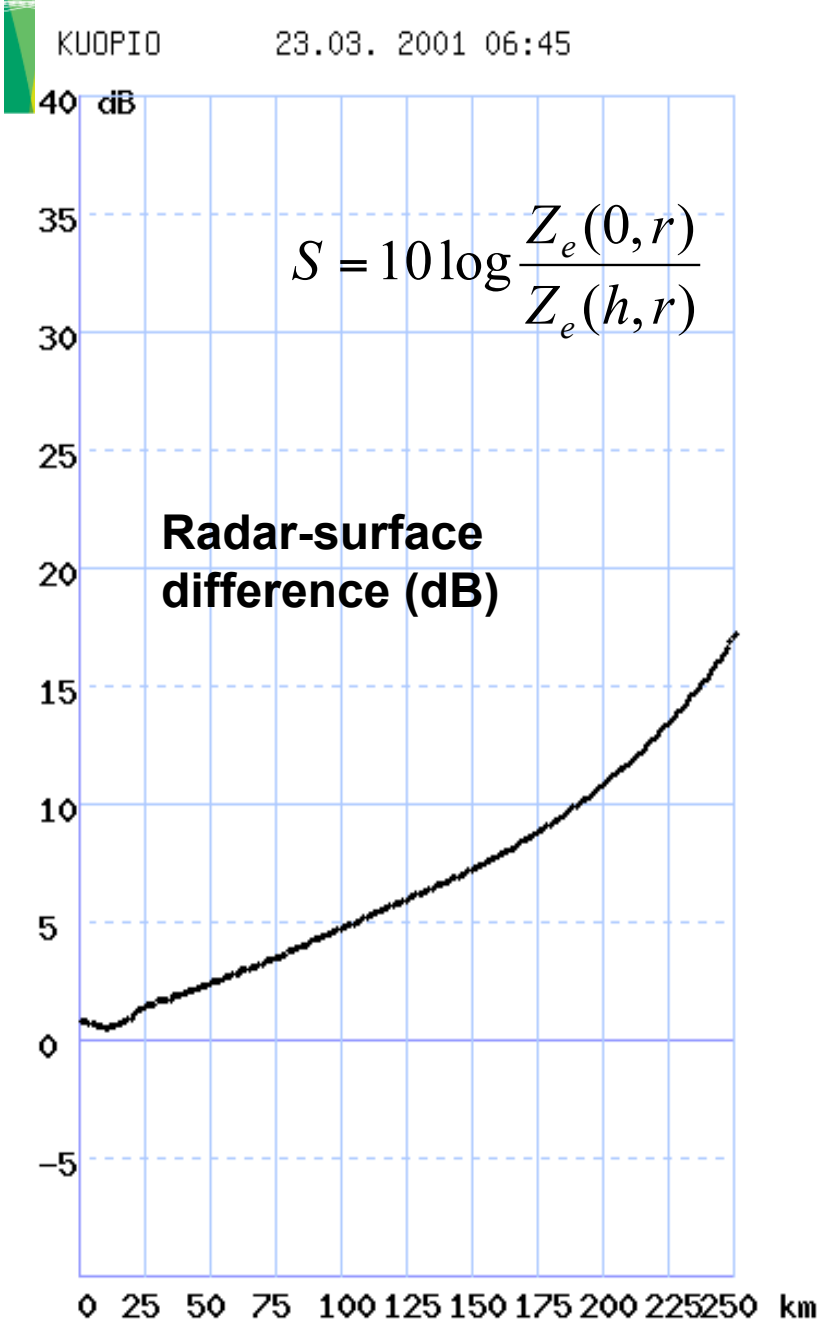
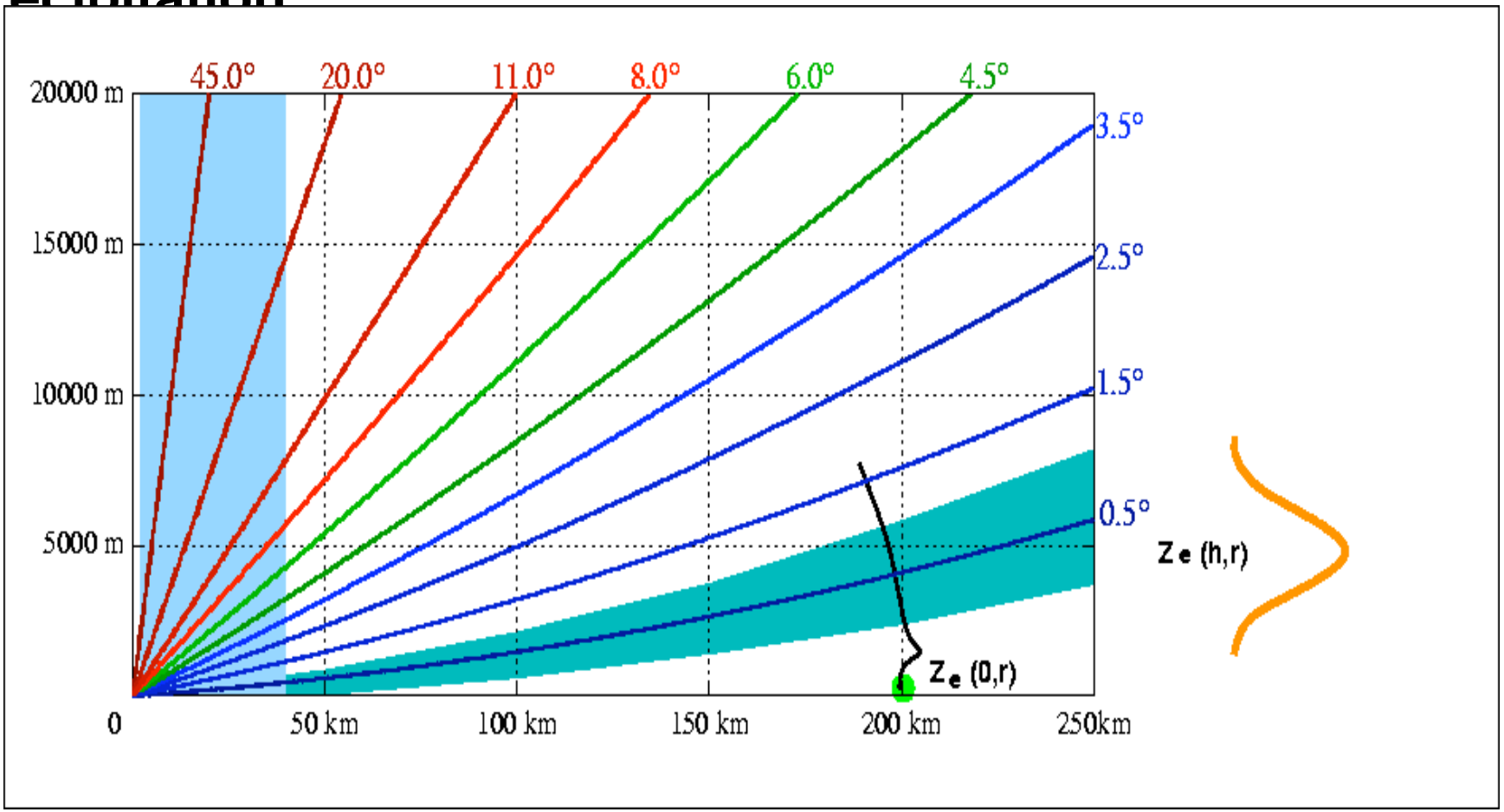
Example: radar-surface difference in a snowfall case





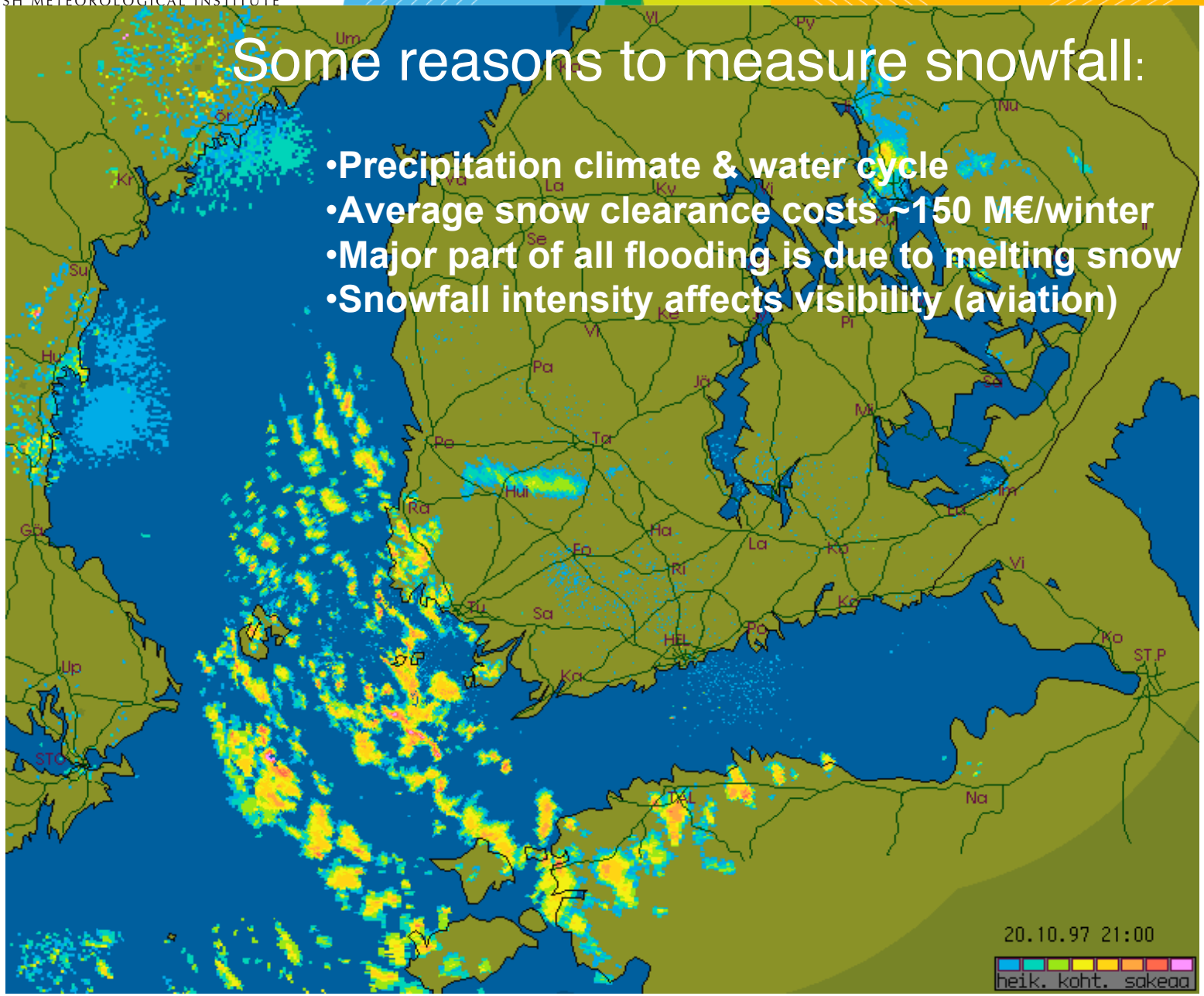
Vertical profiles of reflectivity (VPR) in winter introduce large biases (S) in the radar estimates of surface precipitation

$$S = 10\log\frac{Z_e(0,r)}{Z_e(h,r)}$$



Some reasons to measure snowfall:

- **Precipitation climate & water cycle**
- **Average snow clearance costs ~150 M€/winter**
- **Major part of all flooding is due to melting snow**
- **Snowfall intensity affects visibility (aviation)**



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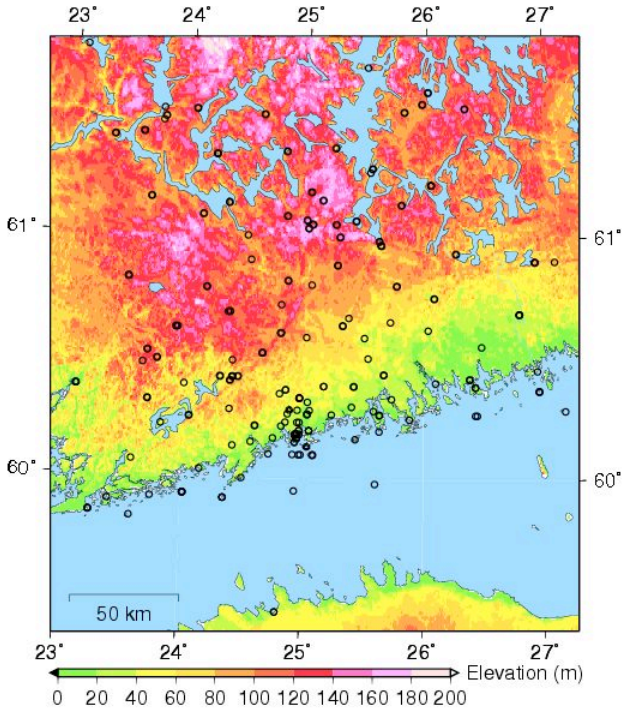
Helsinki Testbed measurements



All other stations shown except Road Weather.

Average WS distance 9 km (FMI regular 50 km).

1 IC lightning system + CG lightning system

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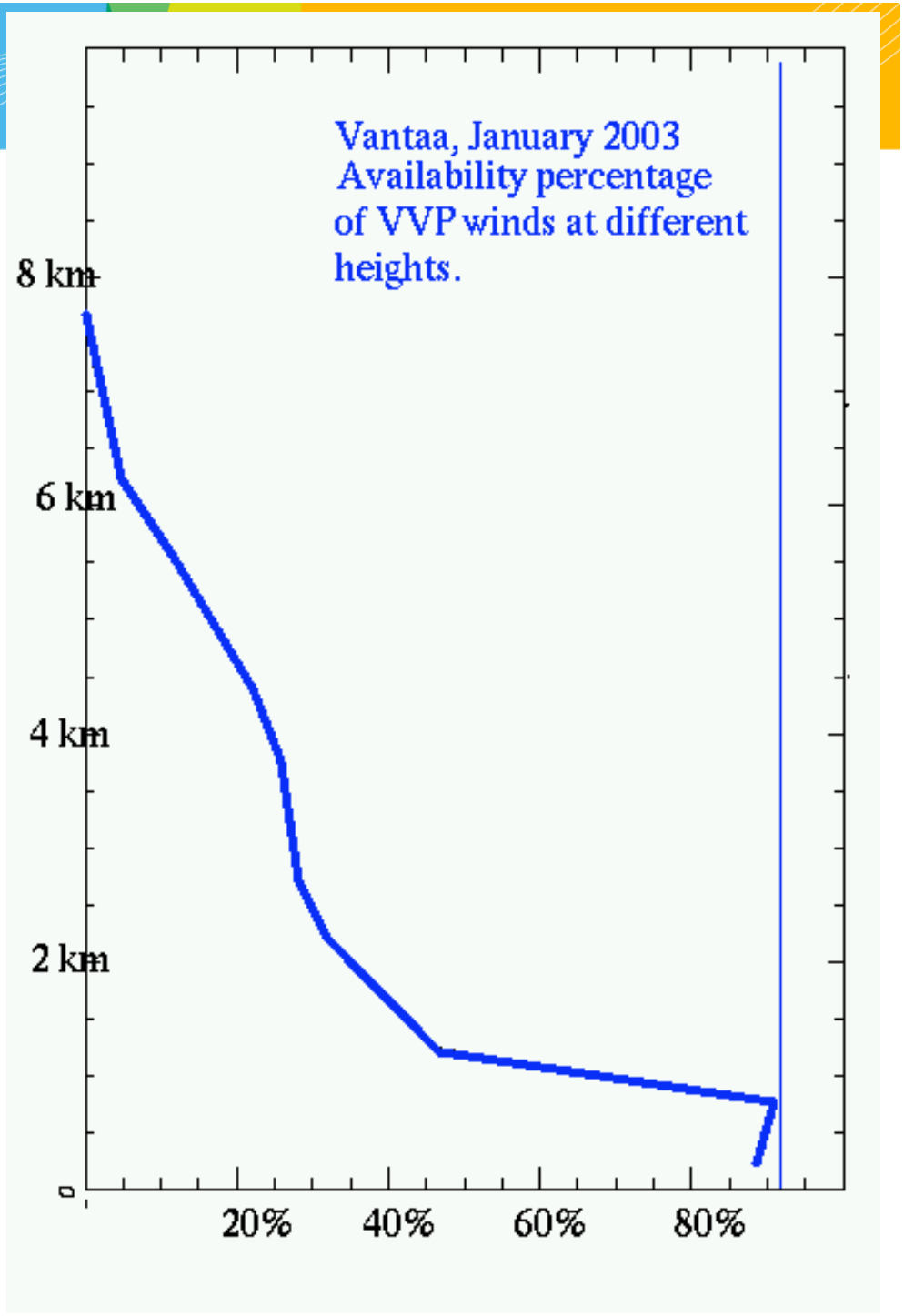
Doppler radars provide winds

- Horizontal drifting of snow particles easily 50-100 km during their fall to ground.
- In boundary layer winds obtainable 90 % of time in winter (ice crystals from the ground ?) with sensitive radars



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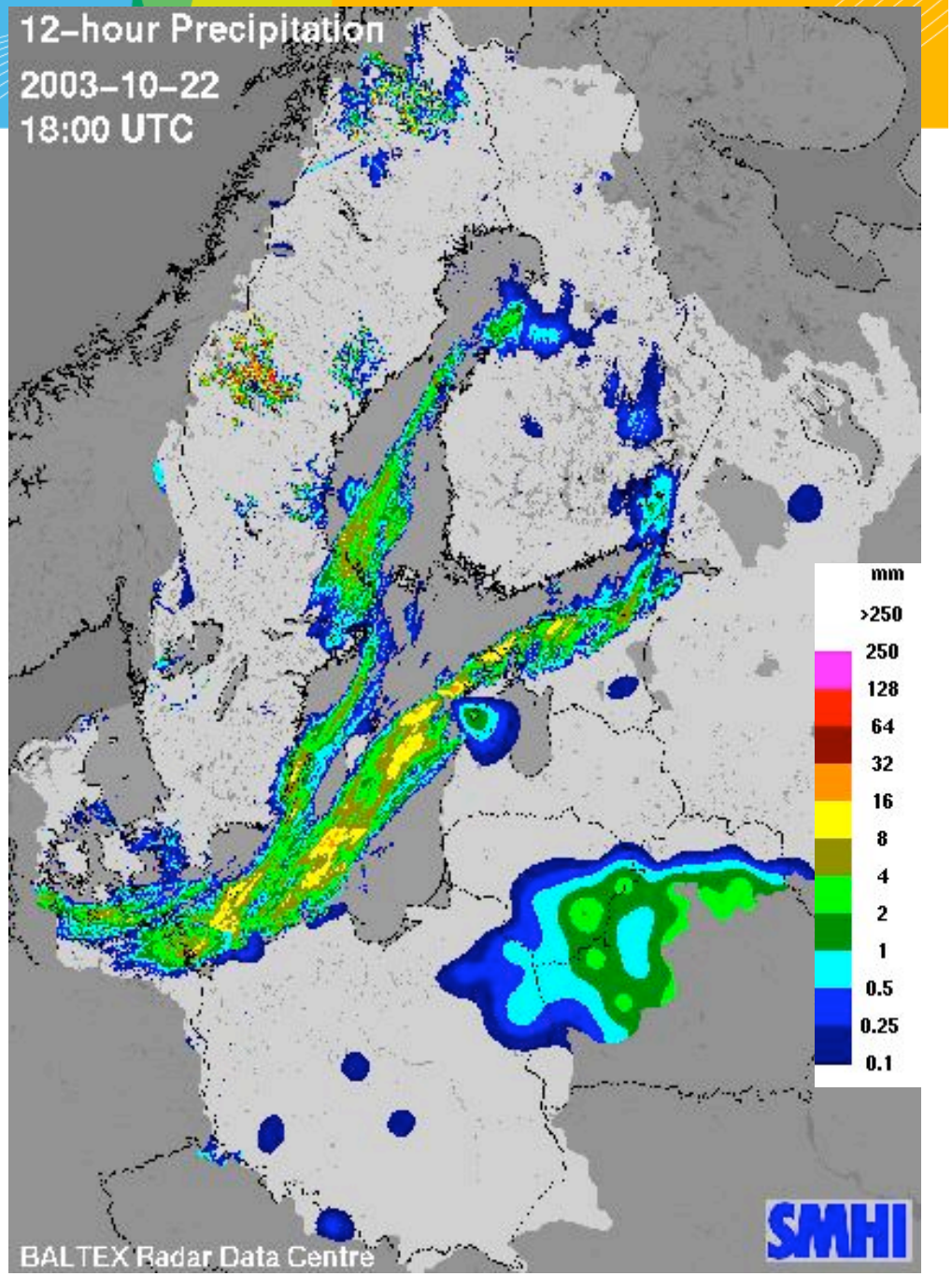
3 and 12-hour gauge-adjusted accumulated precipitation + gauges-only analysis

- 2×2 km horizontal resolution
- Every 3 and 12 hours
- 32-bit depth
- Wind corrected gauge observations
- 3-hour BALTRAD area
- 12-hour BALTEX Region (see example)



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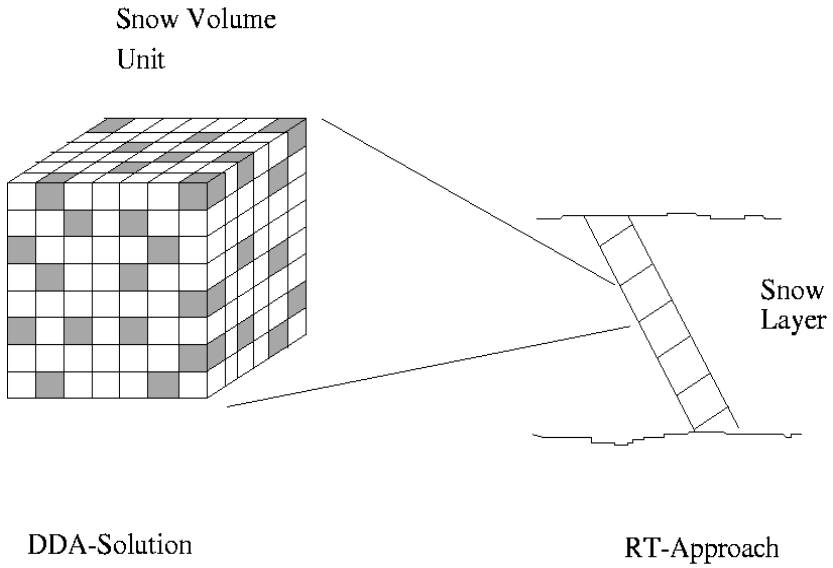
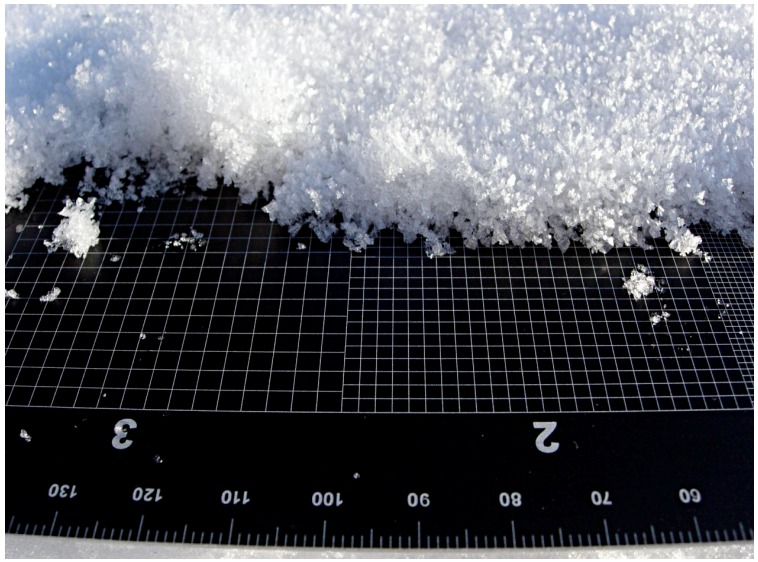
DDA-simulation of polarimetric scattering

Snowfall, snow cover, sleet, insects, birds….

- Modeling of polarimetric quantities applying a general scattering model for remote sensing applications (DDA)
- So far the DDA-model has been applied in microwave scattering from snow cover and from the boreal forest
- Comparison to real measurements => algorithms for diagnostics





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Link: EUMETSAT Hydrology SAF

- **SAF = Satellite Application Facility under EUMETSAT contract**
- **HSAF lead by** *Servizio Meteorologico dell'Aeronautica, Italy*
- **Hydrology SAF**
  - Precipitation (Italy)
  - Soil Moisture (Austria)
  - Snow parameters (Finland)
- **Mainly EUMETSAT operational satellites, but also other (research) satellites are used, when applicable**

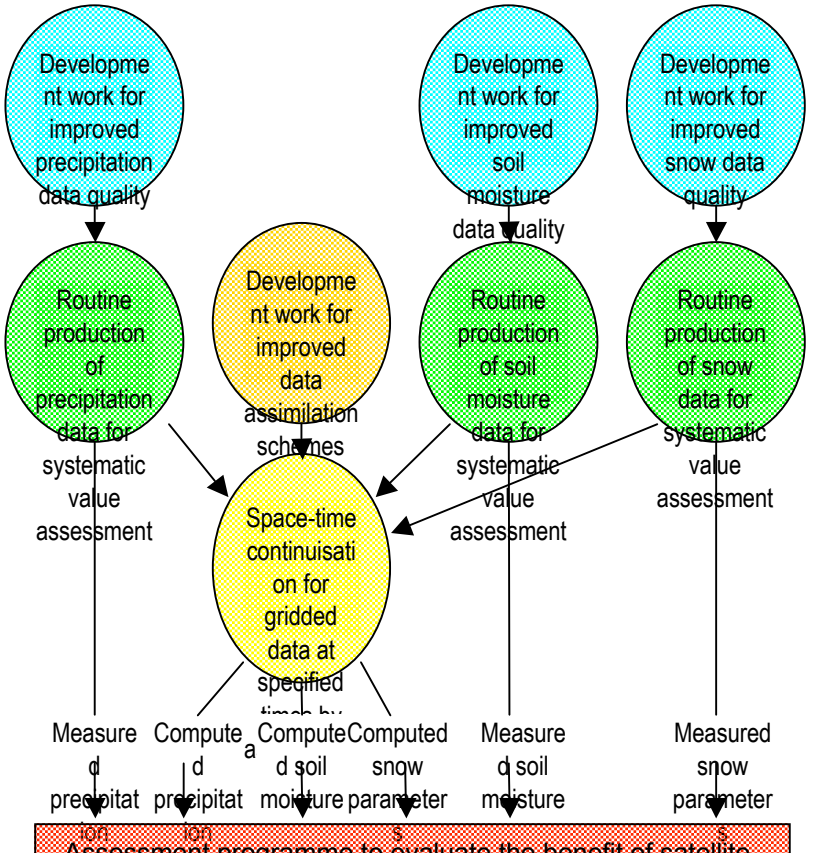

Fig. 01 – Logic of the H-SAF Development phase.

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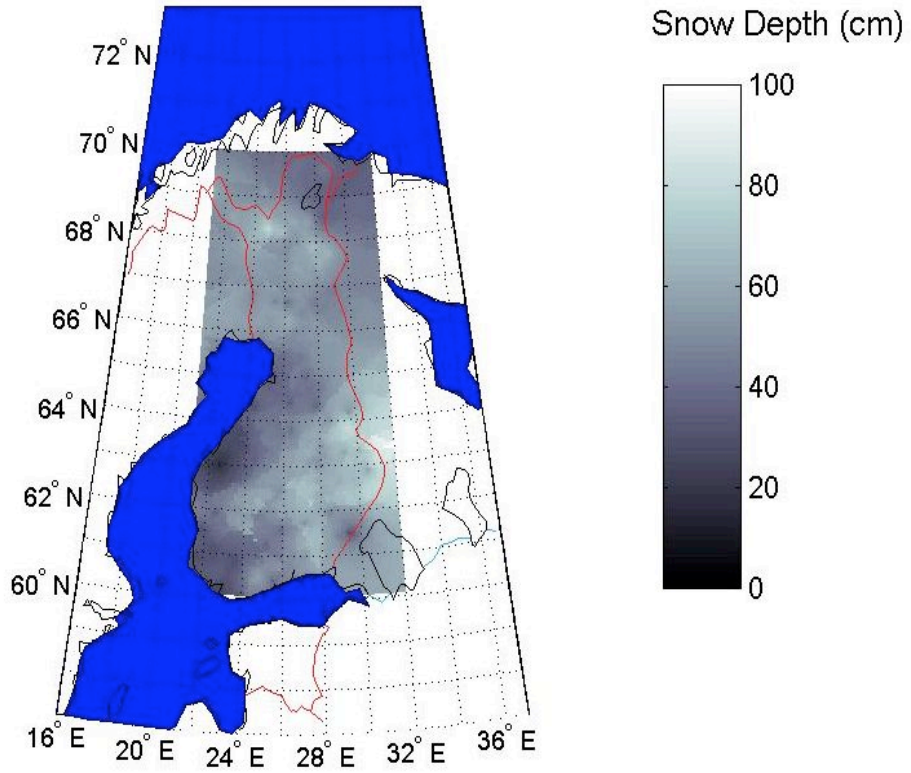
Mapping of snow water equivalent and snow depth from space-borne microwave radiometer data for EUMETSAT H-SAF activities

- **Technology: assimilation of satellite data with *in situ* observations (SD/weather stations or SWE/snow courses)**
- **Applications: operational hydrology and climatology**
- **Users: hydrological models (e.g. floods), climate change studies, hydropower industry, weather forecasting, tourism and transportation**

AMSR-derived SD for 2 Feb. 2004



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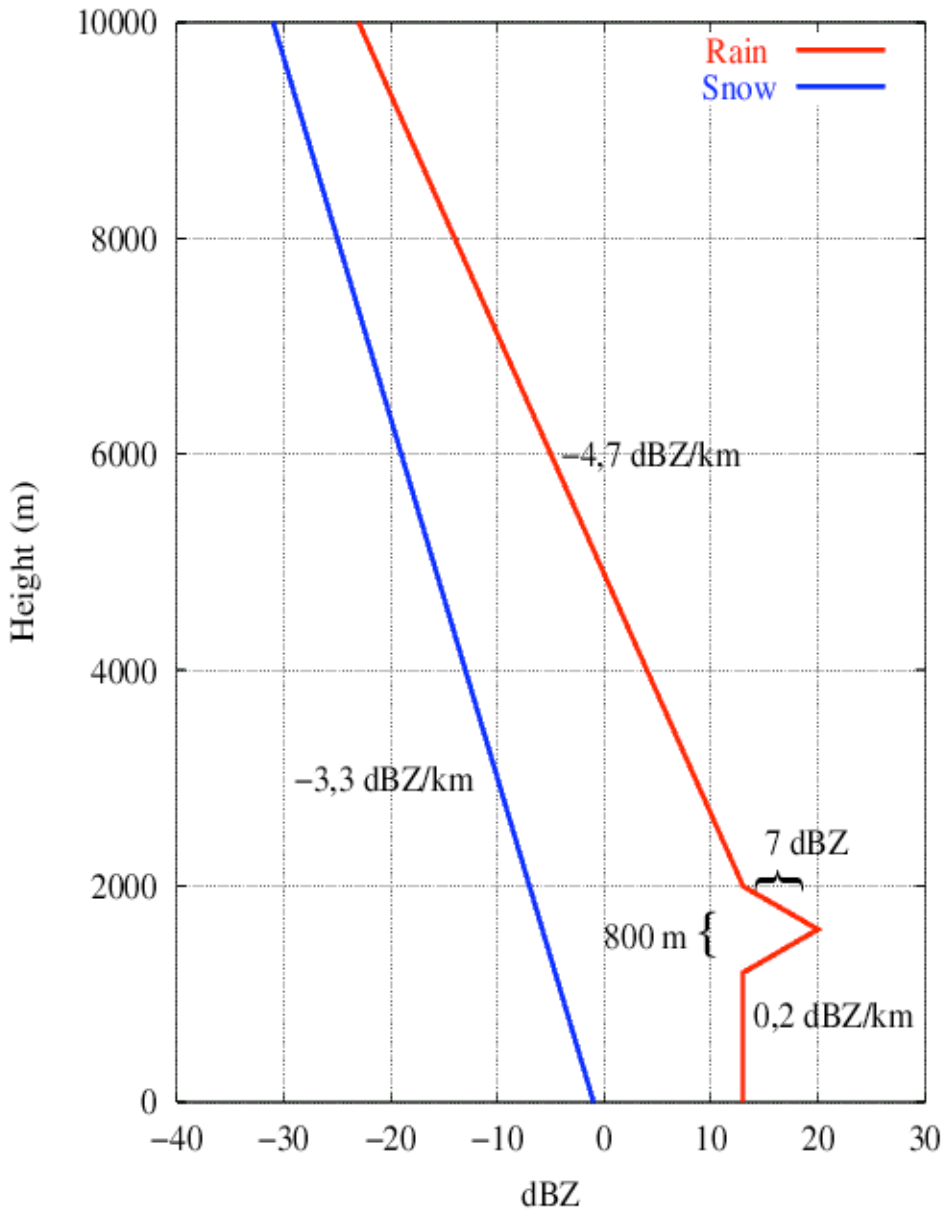
Climatological profiles based on 220 000 measured precipitation profiles



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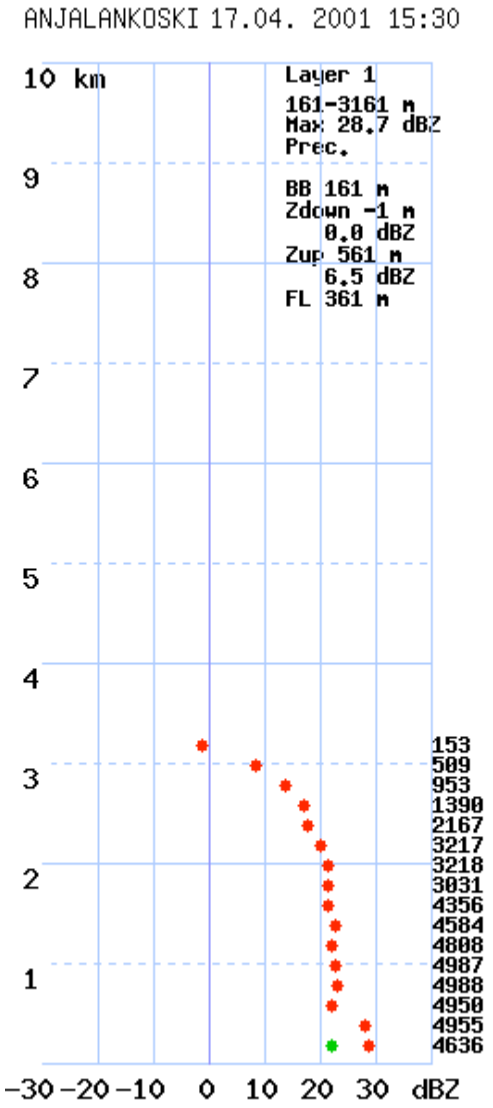
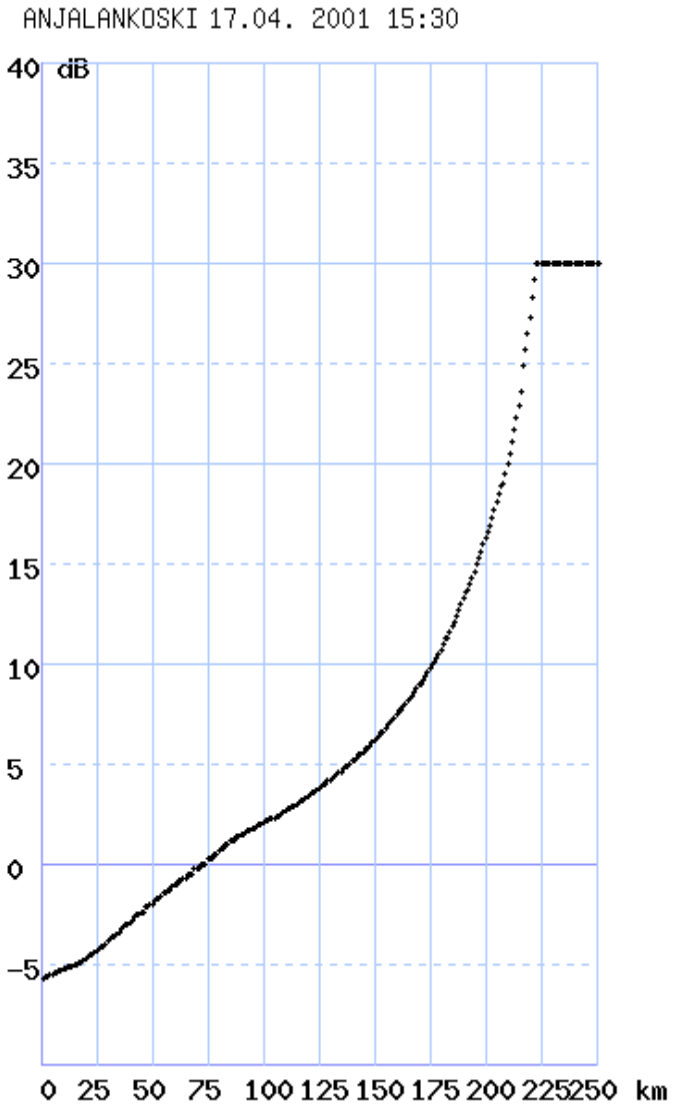
Example: Bright band at ground



Radar bias i.e. VPR correction for 500 m PsCAPPI and dry snow $S(Z_e)$



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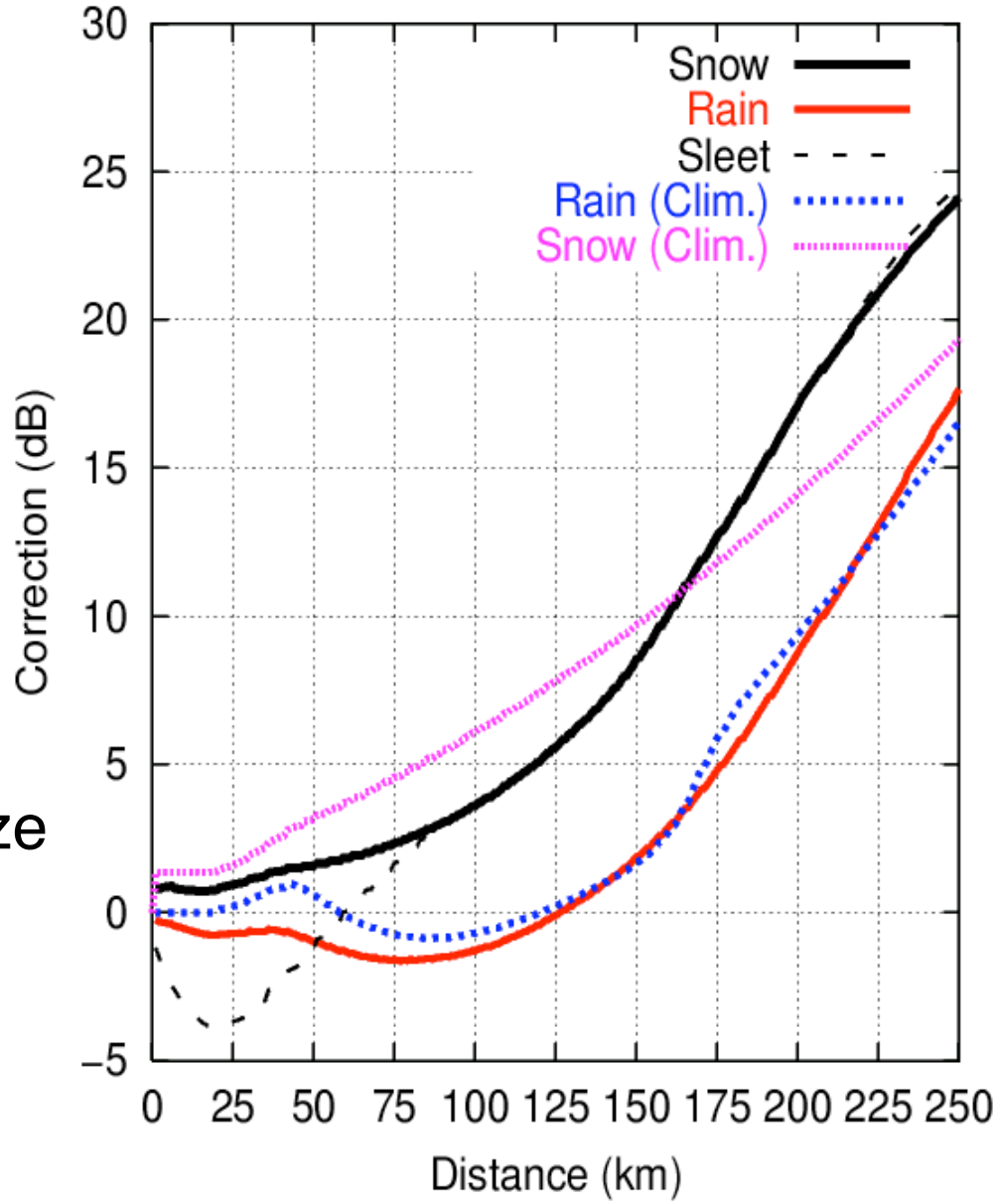
Yearly average sampling bias for 500 m PsCAPPI

Snowfall sample size
106 000 VPRs



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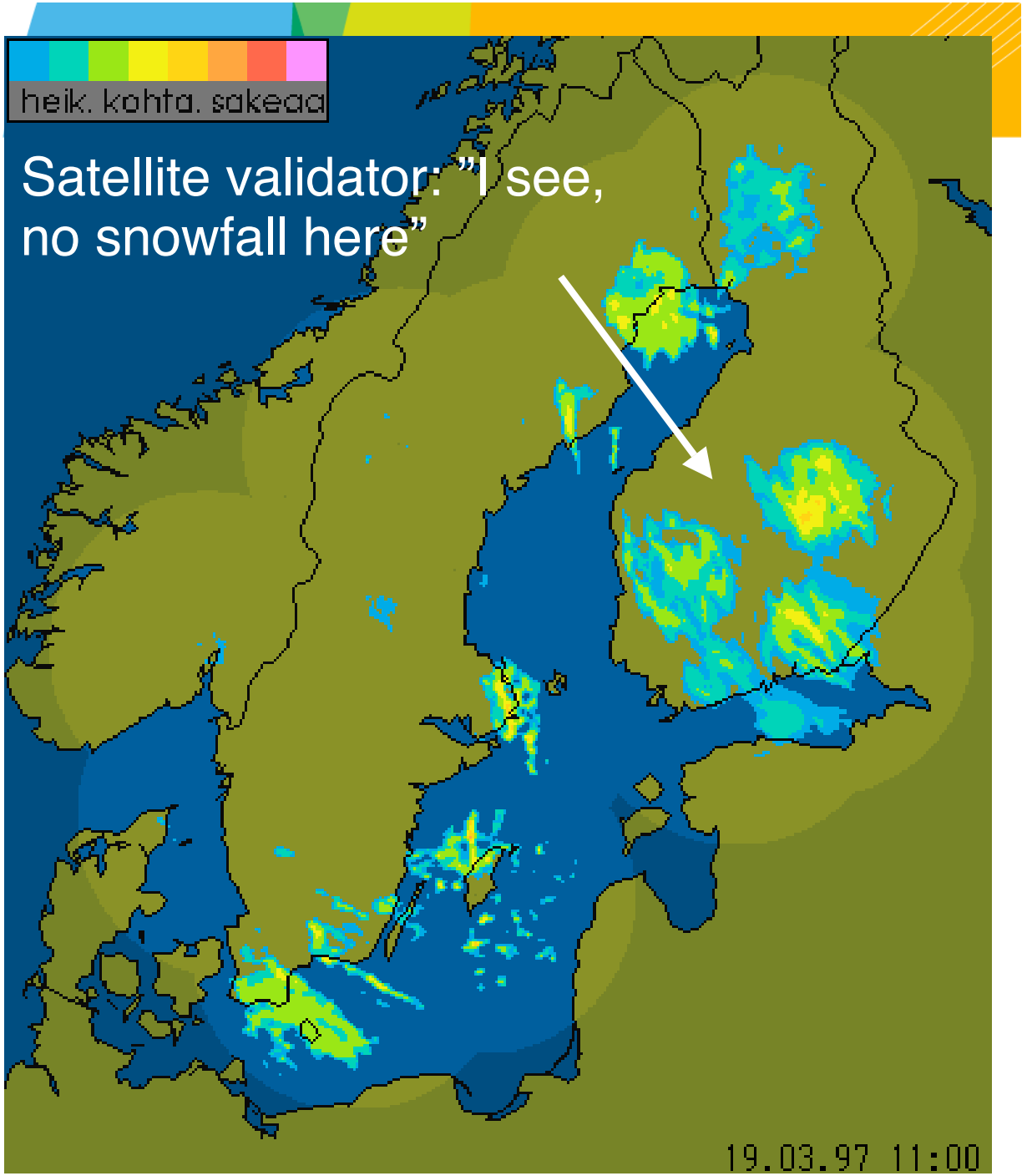
Beam overshooting

- Shallow snowfall often detected only at short ranges

- Adding Probability of Detection (POD) of precipitation at echo free bins will enhance their quality.



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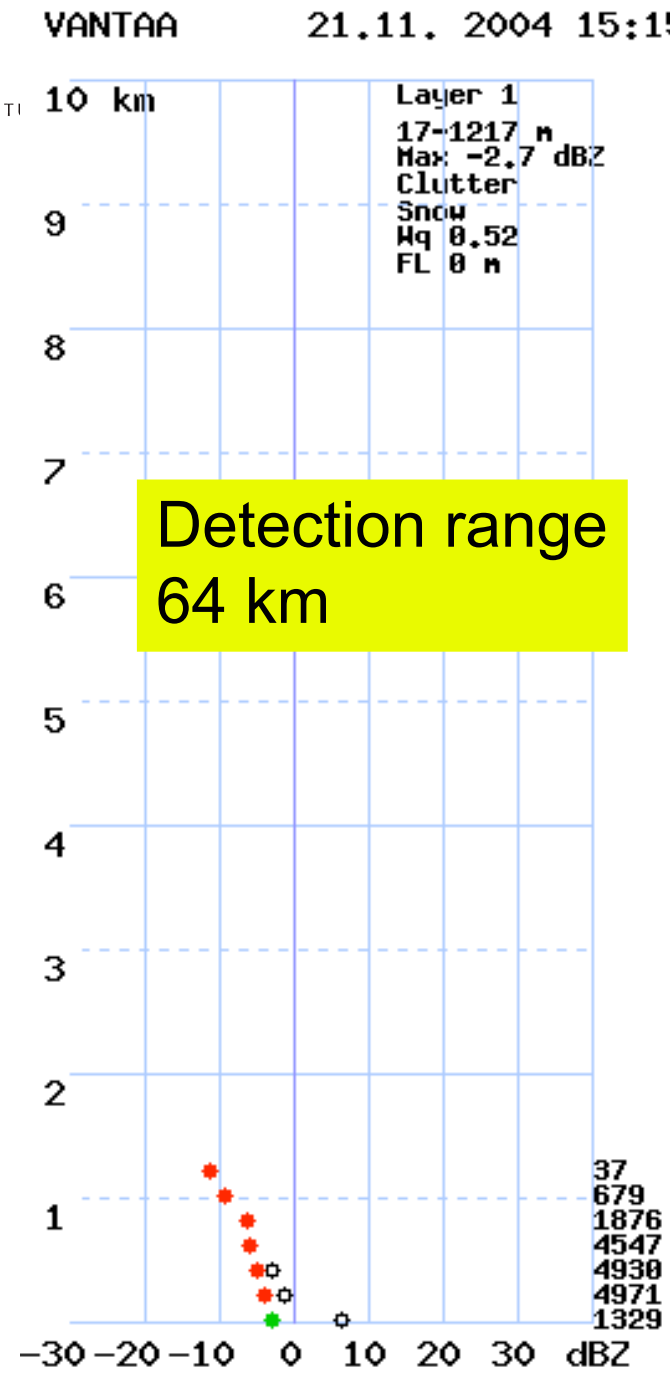
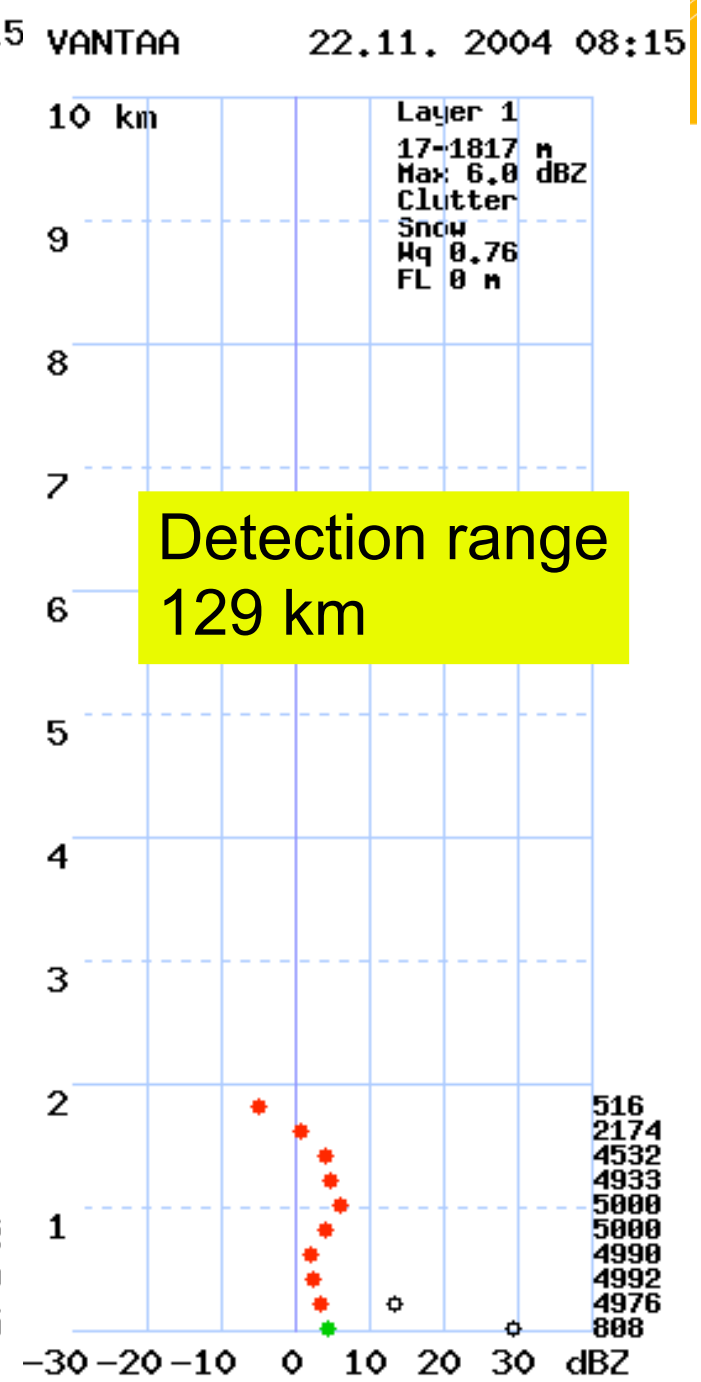
Examples of snowfall detection ranges in the worst cases

(elevation 0.4°, MDS at 1 km ~ -45 dBZ)





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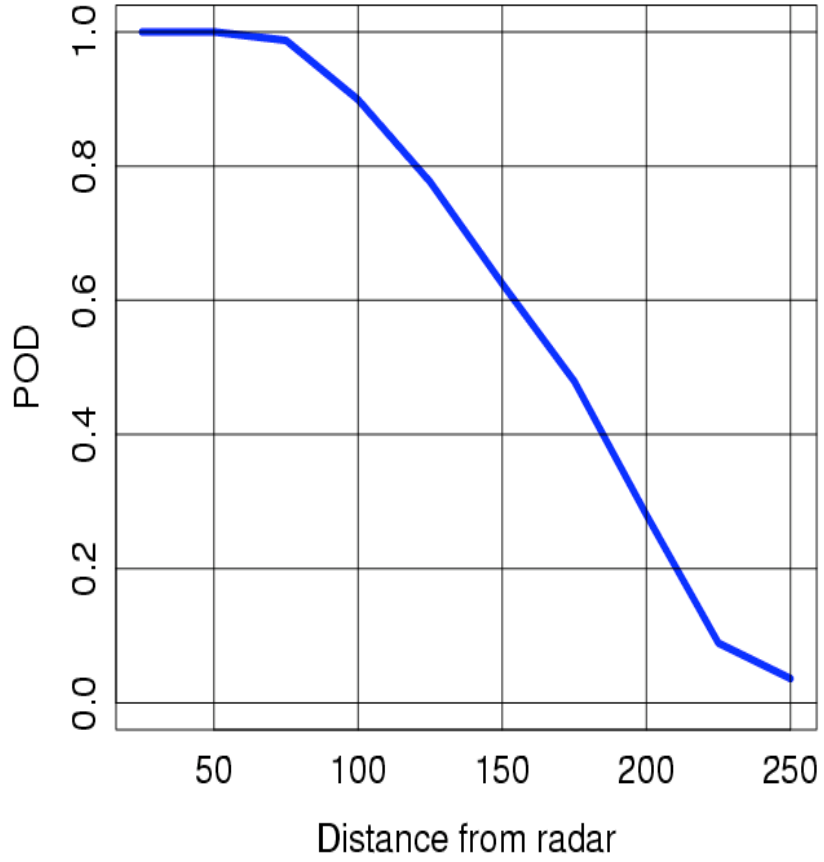
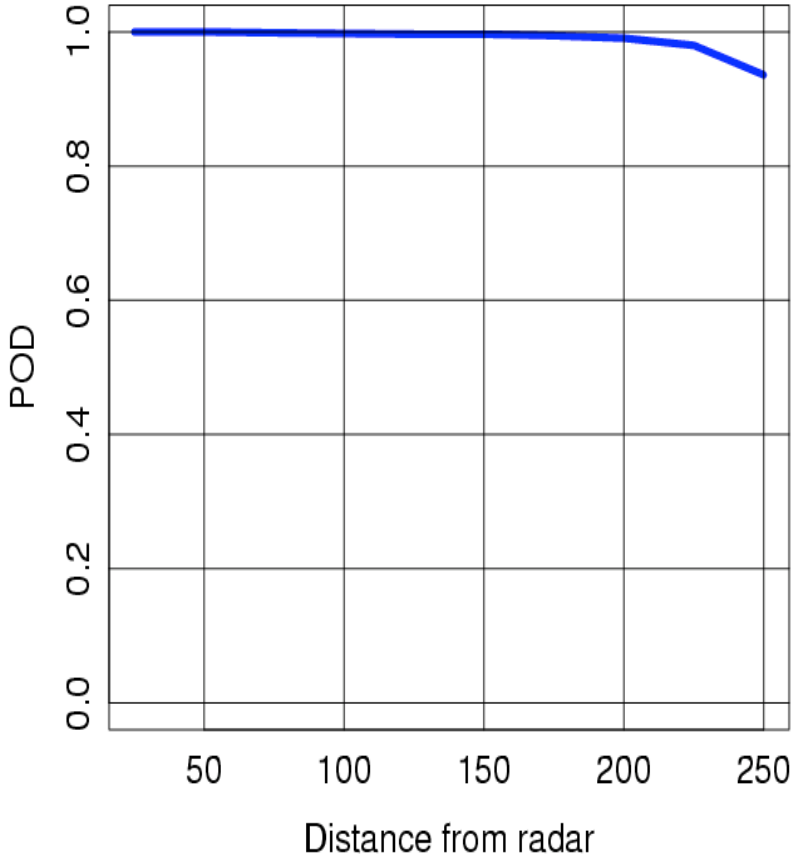
CDFs of the detection range estimate the probability of detection (POD) as a function of range

Nov 20-31, 2004

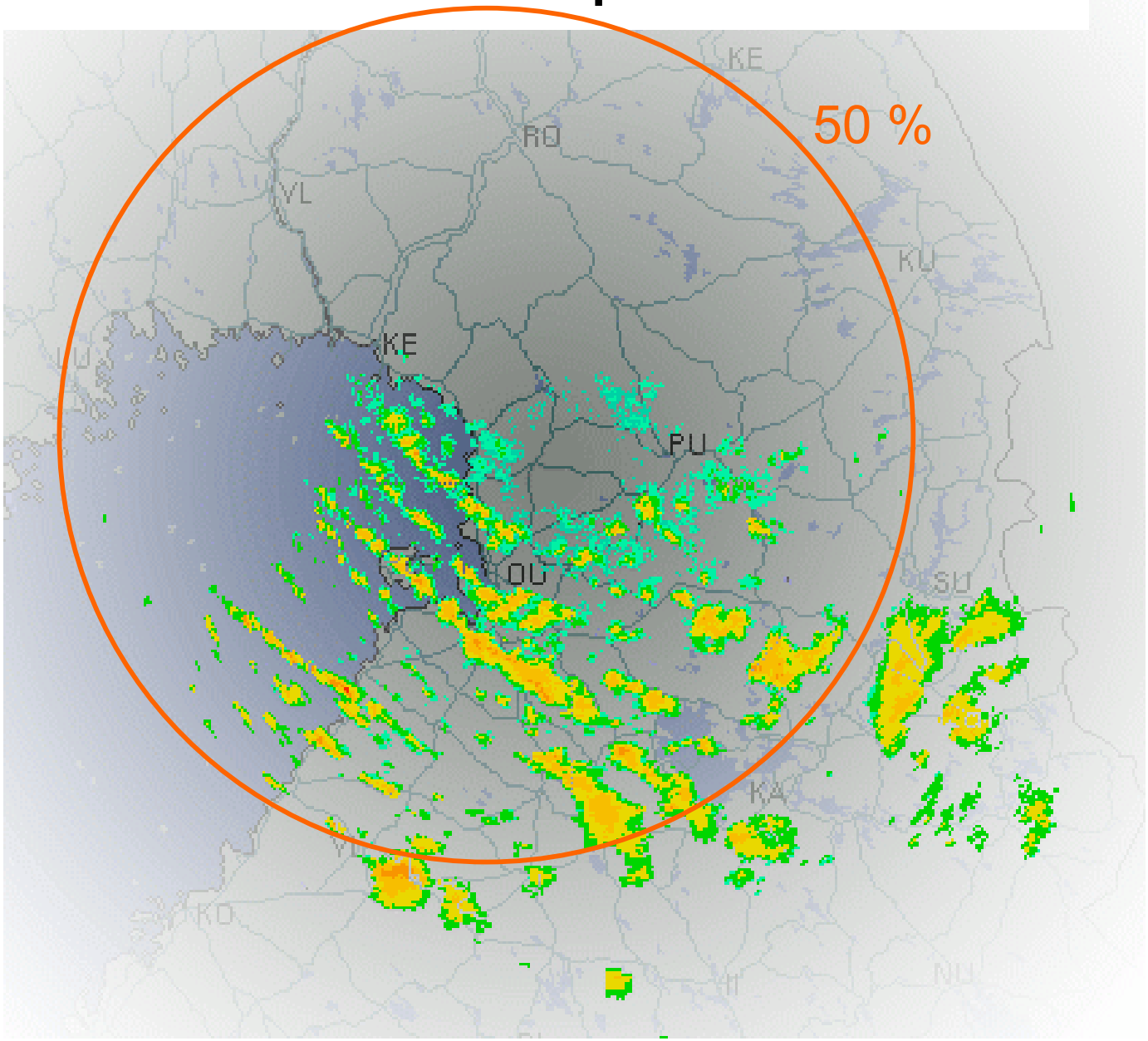


Jul 27 – Aug 5, 2004



Visualisation of POD in the products

- Rings of POD isolines
- Background shading



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IPWG/GPM/GRP Workshop on Snowfall, Working Group on Validation, 12 Oct, 2005

A wide international voluntary will exists among the scientists to participate the GPM GV. However, this will appears only as a vaporware, i.e. no Terms of Reference have been agreed on the following issues:

- **Responsible persons for international management and planning (WG discussion clubs are helpful but have no mandate to decide).**
- **Definitions and terminology (e.g. site categories, such as ”supersite”).**
- **Forms of institutional commitments (institutes, not individual scientists share the data).**
- **Which kind of GV measurements are needed (list of products and their preferencies).**
- **IT architecture, data periods, formats and policies (virtual data warehouse suggested in Taipei WS).**
- **Work plan and schedule (e.g. start testing with a few selected prototype sites in near future, suggested in Taipei WS).**
- **How many international GV contributions are reasonable (must be representative – e.g.science, climates - but acceptance of all voluntary contributions will lead to chaos)?**